**A05002**

# The Northwest Crops Project (1998 through 2003): an on-farm comparison of a 3-year and a 4-year crop rotation under direct seeding for the intermediate rainfall area of eastern Washington

*By*
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## Introduction

In 1997, a group of farmers from Whitman and Garfield counties, WA, initiated an on-farm testing project to help answer their questions about transitioning to direct seeding. Their reasons for wanting to use direct seeding systems follow:
- Reduce soil erosion
- Manage crop residue without field burning
- Improve farm economic stability in an era of volatile markets

The project ran for 6 seasons, 1998 through 2003. WSU Extension, along with NRCS, USDA-ARS, and WSU research faculty provided technical support. A research grant from USDA-SARE (Sustainable Agriculture Research and Education) funded the project from 2001 through 2003, with support from the Palouse, Palouse-Rock Lake, Pine Creek, and Whitman conservation districts. Grower cooperators were John and Cory Aeschliman (Colfax), Lee Druffel (Colton), Tracy and Kye Eriksen (St. John), Ron Kile (Pine City), Steve and Dan Moore (Lacrosse), Randy and Aaron Repp (Dusty), David and Paul Ruark (Pomeroy), and Steve and Ann Swannack (Lamont).

We gratefully acknowledge the project statistician, J. Richard Alldredge, Department of Statistics, WSU, for his help and patience in assisting with the data analyses.

## Methods

The project objective was to compare a 3-year crop rotation with a 4-year rotation, all under direct seeding without irrigation or field burning. The 4-year rotation was spring wheat - winter wheat - warm season grass (corn) - broadleaf crop (cooperator’s choice). The 3-year rotation was winter wheat - spring barley - chemical fallow or broadleaf crop (cooperator's choice). This rotation followed closely a conventional rotation for the area, substituting chemical fallow for tillage fallow. The cooperators also selected the crop varieties that best suited their farms. For practical reasons such as space, plot layout, and fiddle factor, the project did not include a check rotation under tillage. The grower cooperators wanted to learn how to make direct seeding work, and were more interested in comparing rotations within that system.

Each farm had 1 replication of each rotation (1 site had 2 replications) for a total of 8 replications of both rotations. Each crop in the rotation was grown every year, so that each site had 7 plots (4 for the 4-year and 3 for the 3-year rotation). At each site, the plots were randomized, but every plot followed in its designated rotation throughout the project. The plots were 500 to 700 feet long and 30 to 60 feet wide, to accommodate the growers' existing farm equipment for spraying, seeding, and harvesting. All the experimental sites were in the intermediate rainfall area (14 to 18 inches annual precipitation) and were on Athena silt loam soil.

The farmers shared a John Deere 7000 6-row corn planter, but used their own direct seed drills for the rest of the plots. Drill types used were: Colfax - Great Plains double disk drill with turbo coulter; Dusty - John Deere 752 single disk drill; Lamont - IHC 150 with modified hoe openers; St. John - AgPro double disk drill; Lacrosse - Great Plains double disk drill with turbo coulter; Colton - Flexicoil 6000; Pomeroy - John Deere 752 single disk drill; Pine City - Concord air seeder with Anderson hoe openers. The cooperators did not use any form of tillage or harrowing operations to manage residue, but seeded directly into standing stubble.

We collected soil samples from each plot in Fall of 2003 for DNA analysis to determine the presence and levels of various soilborne pathogens in each rotation. The results of this study are reported in Appendix A.

Each year, prior to spring planting we took 4-ft soil samples, 3 per plot for moisture and nutrient analysis as a basis for fertilizer applications. Every season we collected yield and test weight data from the plots and the farmers compiled their operating costs. Yield and economic return were the primary factors of interest to the growers. In April 1998, at the beginning of the project, WSU scientists collected the following soil quality data from each site: pH, organic matter (OM) levels, earthworm counts, and bulk density. They repeated these tests again in Spring 2003, to determine overall changes in soil health and quality during the project. The results are shown in Appendix B.

In 2002 and 2003, we took stand counts (number of plants per 3 ft of row, repeated 3 times per plot at random locations) about 1 month after seeding. Stand establishment is a measure of successful seeding technique and would highlight any potential problems with the farmer's drill. In 2002 and 2003, we also took weed counts on the plots to study any changes in weed species that might occur with the change to direct seeding. However, 2 years' data were insufficient for inclusion in this report.

## Results and Discussion

*The Theories*

The 3-year rotation, winter wheat - spring barley - chemical fallow or broadleaf crop, was very similar to the local conventional rotation of winter wheat - spring barley - summer (tillage) fallow. This rotation is centered on winter wheat, the grain crop that typically provides the best economic return in eastern Washington. In the conventional 3-year rotation, farmers use tillage fallow to control weeds and provide moisture in the seed zone so the winter wheat crop can germinate and establish well before winter.

In the 3-year direct seeding rotation, farmers used herbicides instead of cultivation to manage weeds in the fallow year. With chemical fallow the farmer does not create dust mulch at the soil surface that holds moisture in the seed zone, so establishing winter wheat was tricky in the dry fall weather that prevailed during this project. Also, repeated use of herbicides in chemical fallow that have the same mode of action will favor herbicide resistant weed species. However, determining shifts in weed biotypes was beyond the scope and time of this project.

The 4-year rotation was spring wheat - winter wheat - warm season grass (corn) - broadleaf crop (cooperator's choice). This was a diverse, but also a high-risk rotation that Dr. Dwayne Beck, South Dakota State University, had shown to be successful in the Pierre region of South Dakota. The corn as a warm season grass had a late seeding date (usually May 10-25), providing a longer window in the spring for managing spring emerging weeds. It would also enable the growers to diversify their herbicide use to slow development of herbicide resistant weed species. We hoped that incorporating a broadleaf and a warm season grass into the rotation would help break disease cycles, especially soilborne diseases that are endemic to the region, such as *Rhizoctonia*, *Pythium*, and Take-all. However, concurrent research at other locations revealed that these pathogens, especially *Rhizoctonia*, have a very wide host range that includes many of the broadleaf crops we tried in this project (Cook et al., 2002a).

The warm season grass (corn) has a more efficient photosynthetic process than cool season cereals such as wheat and barley, which enables it to produce huge amounts of biomass. Large corn stalks, when left as residue on the soil surface, are effective in reducing soil erosion. However, warm season grasses need warm days and warm nights (though they shut down when the temperature gets above 85ºF or below 50ºF) plus summer rainfall in order to thrive. Dryland eastern Washington is low in heat units and summer moisture, so it is a marginal area for corn production. Marcos et al. (1998) showed that 2400 heat units are needed for short-season hybrids. They also showed that at Pullman, corn will freeze before physiological maturity 18% of the time. Nevertheless, Washington is a corn-deficient state, and some of the project participants remain optimistic that growing corn provided them with agronomic benefits. They believe it has a fit in their rotation, especially if they can market it locally without having to dry the grain after harvest.

There is a broad spectrum of herbicides labeled for use with corn, which allows more herbicide diversity in the rotation. However, the scope and length of the project did not allow us to measure shifts in weed species or levels of herbicide resistance.

Decaying roots of corn and tap-rooted crops such as canola or mustard, when left undisturbed in the soil, should allow for increased water infiltration into the soil. However, some eastern Washington farmers who have direct seeded for 6 or more years, and have rotated with broadleaf crops, are finding hardpan layers at the depth of their seed drills. This is contrary to expectation, though WSU researchers have documented that, with several years of direct seeding, a compaction layer developed about 6 inches below the surface (Fuentes et al, 2003).

*The Project Results*

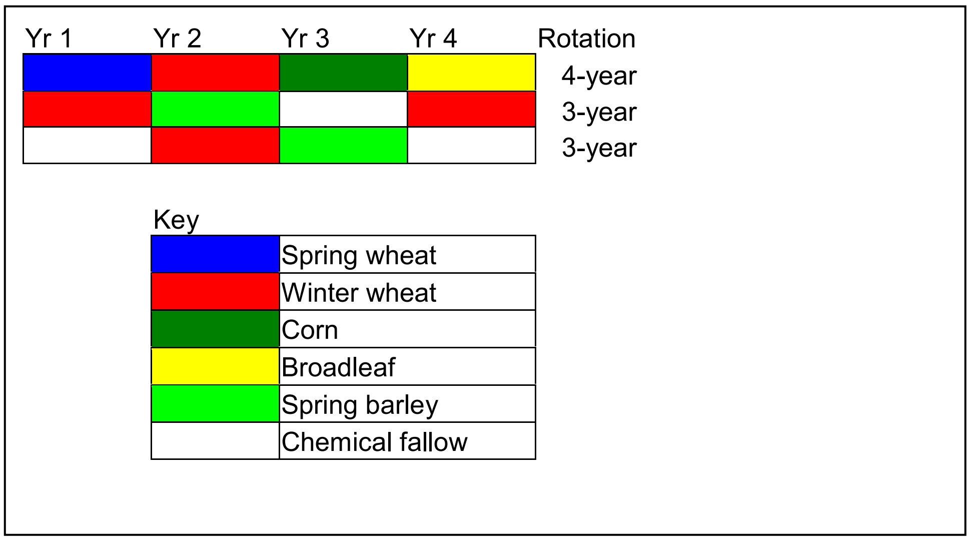
Initially there were 8 replications of each treatment (rotation). However, during the 6 years of the project, "stuff" happened that reduced the effective number of replications and plots:

- One grower operation quit the project after the 2000 season because the partners felt overall that direct seeding was not working for them.
- Another grower decided after the 2001 season that his plots were not contributing useful data to the project. They were located on the breaks of the Snake River, and deer and elk moving up from the canyon decimated the corn and broadleaves every year. Also, the prevailing wind was at right angles to the plots, so herbicides tended to drift and damage adjacent crops. As the strips were only 30 feet wide, it did not leave enough healthy crop to harvest.
- One cooperator operation had to move the plots to another location after the 2000 season as they were in a very frost-susceptible area. However, the new location also had frost and weed problems.
- The cooperators established the plots in the spring of 1998, so they all seeded spring wheat in place of winter wheat that season. This reduced the effective size of the data set for that year.

- A variety of planting mistakes occurred at some locations during the project. These all reduced the number of effective plots or replications, which made it difficult for the statistical program to detect differences between crops or rotations that were likely to recur in successive seasons.

Another factor that complicated the analysis was trying to compare a 3-year with a 4-year rotation, as the comparison would not be balanced (Figure 1).

Figure 1. Schematic diagram of a 3-year and a 4-year crop rotation within the Northwest Crops Project.




If one compares the rotations over 4-year periods, it would favor the 3-year rotation if it had 2 years of winter wheat, and would penalize it if it had 2 years of chemical fallow or a poorly adapted broadleaf crop. Alternatively, comparing data from 4 years with data from any 3 years would bias the comparison depending on whether the fourth year was a good or poor crop season.

Comparing the 2 rotations over 3-year periods would mean the 4-year rotation would be incomplete. Obviously, comparing the rotations over 12 years would reduce these concerns, but was not a practical solution. What we decided to do was make “rolling 4-year comparisons” of the 4-year versus the 3-year rotations. For example, the 4-year rotation data from 1999 to 2002 were compared first with the 3-year rotation data from 1999 to 2001, then from 2000 to 2002.

Table 1 shows the average crop yield for each rotation at each site for every year of the project. At every site, each crop in a rotation was represented each year. For example, there would be 4 plots of the 4-year rotation: winter wheat, corn, broadleaf (peas or canola), and spring wheat. The data points shown would be the average yield of these 4 plots, converted to lb/A for uniformity. Each data point for the 3-year rotation would be the average of 3 plots at each site.

Table 1. Average annual yield (lb/A) for each rotation at each site within the Northwest Crops Project.

| Site | Rotation | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | Average (lb/A) |
|---|---|---|---|---|---|---|---|---|---|
| Colfax | 4-year | | 3208 | 2819 | 3199 | 2355 | 2097 | 1245 | 2,487 |
| | 3-year | | 2807 | 2744 | 2626 | 2132 | 2101 | 1942 | 2,392 |
| Dusty | 4-year | | 3100 | 3027 | 3974 | 3296 | 2624 | 2370 | 3,065 |
| | 3-year | | 2602 | 2797 | 2687 | 2685 | 2663 | 2502 | 2,656 |
| Lamont | 4-year | | 1118 Φ | 2519 Φ | 2133 | 849 | 1542 | 1156 | 947 |
| | 3-year | | 950 Φ | 1995 Φ | 1828 | 1162 | 1435 | 1272 | 1,440 |
| | Reverse 4-year | | 1118 Φ | 2519 Φ | 2088 | 764 | 1672 | 1095 | 936 |
| St John | 4-year | | | | | 1924 | 958 | 1635 | 1,506 |
| | 3-year | | | | | 864 | 400 | 1280 | 848 |
| Pomeroy | 4-year | | 3863 | 1200 | 3254 | 1515 | 2315 | 4095 Ω | 2,025 |
| | 3-year | | 2637 | 1862 | 2258 | 2415 | 2013 | 3460 Ω | 1,864 |
| Colton | 4-year | | 3731 | 2053 | 2570 | 1290 | | | 1,607 |
| | 3-year | | 3276 | 2553 | 3047 | 1533 | | | 1,735 |
| Lacrosse | 4-year | 2683 | 3178 | 2121 | 3184 | | | | 2,792 |
| | 3-year | 2620 | 3453 | 2267 | 3440 | | | | 2,945 |

Φ Yields of same crops in different plots and rotations were averaged at harvest.
Ω In 2003, winter wheat was seeded across all plots, but the plots were harvested separately.

The 4-year rotation was spring wheat - winter wheat - warm season grass (corn) - broadleaf crop (cooperator's choice). The 3-year rotation was winter wheat - spring barley - chemical fallow or broadleaf crop. Table 1 does not differentiate between these variations, as they were not consistent from year to year. However, we did break out these differences in the statistical analysis. The producer decided which broadleaf crop to grow, or whether to put that plot into chemical fallow, based on price and moisture considerations for that season. When one of the plots was in chemical fallow, we included the yield (zero) and the input costs in the analyses because this would be the yield and impact on the rotation in real life. It was an inherent goal of the project to allow the cooperators to make decisions on the plots similar to what they would do on a whole field basis, in an attempt to meld practical farming with research.

The reverse 4-year rotation at Lamont was a repeat of the standard 4-year rotation, except that spring wheat followed winter wheat. This reverse 4-year rotation was repeated at Dusty, but due to a planting error was not consistent throughout the project.

It is important to note these yields were for relatively small experimental plots, less than 1 acre in size, and were not representative of whole fields or the whole farm. In general, the cereal plots (wheat and barley) had yields fairly consistent with what one would expect for the area. However, crops new to the area: corn, mustard, and canola, reduced the yield averages. They do not have a 100-year history of breeding programs to support their adaptation to the area, so expecting them to perform with the same economic return as the cereals was a tall order. It was often difficult getting an adequate plant stand for several reasons. Setting the drills at the correct rate and depth for very small seeds was sometimes challenging with these crops. For example, if the duff layer were thick, ensuring good seed to soil contact and moisture might mean the seeds were too deep for optimum germination. These unadapted crops tended to suffer from cold conditions at seeding, and also from frost damage. For example, 2 years there were freezing temperatures in May that killed canola. In 2002, the peas at one location died at the seedling stage, and residual from a previously applied soil active herbicide appeared to have caused the damage. Also in 2002, the plots experienced frost every month of the year. This highlighted the variability in our climate, which is not so noticeable when growing well-adapted crops.

Using farm-size equipment on relatively small plots created some problems with herbicide applications. Also, the alternative crops tended to be very attractive to wildlife. Deer and elk often decimated the corn in the fall when nothing else was green. However, when the farmers grew it in large fields (at least 100 acres), the damage was minimal and mostly confined to the field borders. In order to get a corn yield, we estimated the yield from a sample hand-harvested from each plot during the last week of September, when the grain was between 18% and 25% moisture. We used that measurement rather than what the farmer actually harvested (see Appendix C for comparisons between methods). Also, a reality of on-farm testing is that the plots are often an inconvenience to the farmers, who tend to put them lower on their management priority list than large fields. Consequently, the timing of seeding, harvest, and other management operations was not always optimal.

Crop yields at the Lamont site were considerably lower than at the other locations. While most of the years of this project were drier than normal, the site was exceptionally dry, especially in 2002 and 2003. These plots also incurred damage from deer and birds. Pheasants caused quite a lot of damage in the corn plots at most sites, and some years more than others, by pecking the seed out of the ground. Farmers in the Midwest have dealt with this problem by mixing cornmeal in the drill box, so the smell of corn is in a line, not concentrated at the seed location, Again, damage in larger cornfields was less noticeable.

The corresponding economic data for the rotation yields are in Table 2. The net return was calculated as gross revenue minus the sum of fixed and variable costs. We used the same crop prices for each site and across all years of the project. They were: soft white wheat - $3.86/bu; spring barley - $92/ton; spring peas - $7.00/cwt; spring canola and mustard - 11 c/lb; and corn - $2.60/bu. The fixed and variable costs were from operating costs the growers provided, so they varied with each site and crop. Although 3 of the cooperators used a custom harvester for corn at a rate of $30/acre, these data reflect a cost for corn harvest provided by producers who used their own combines, as this is what they would do if growing corn on a whole field scale.

Table 2. Annual net return ($/A) for each rotation at each site within the Northwest Crops Project.

| Site | Rotation | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | Average ($/A) |
|---|---|---|---|---|---|---|---|---|---|
| Colfax | 4-year | | $24.17 | $16.14 | $34.85 | $9.43 | -$4.27 | -$34.00 | $7.72 |
| | 3-year | | $7.16 | $12.04 | $13.56 | -$1.12 | -$1.50 | -$8.08 | $3.68 |
| Dusty | 4-year | | $22.41 | $21.33 | $59.77 | $32.03 | $4.33 | $0.44 | $23.38 |
| | 3-year | | $19.93 | $32.58 | $27.66 | $25.59 | $24.71 | $21.09 | $25.26 |
| Lamont | 4-year | | -$61.25 Φ | -18.06 Φ | -$30.35 | -$81.18 | -$51.37 | -$66.00 | -$38.15 |
| | 3-year | | -$64.82 Φ | -$22.44 Φ | -$26.80 | -$54.30 | -$42.12 | -$55.10 | -$44.26 |
| | Reverse 4-year | | -$61.25 Φ | -18.96 Φ | -$32.21 | -$69.60 | -$46.18 | -$69.91 | -$36.32 |
| St John | 4-year | | -$35.62 | -$80.49 | -$43.69 | | | | -$53.27 |
| | 3-year | | -$58.66 | -$83.17 | -$42.41 | | | | -$61.41 |
| Pomeroy | 4-year | | $55.48 | -$41.39 | $31.04 | -$44.43 | $6.99 | $73.94 Ω | $1.28 |
| | 3-year | | $14.99 | -$22.63 | $5.71 | -$15.61 | -$2.02 | $47.71 Ω | -$3.26 |
| Colton # | 4-year | | | | | | | | |
| | 3-year | | | | | | | | |
| Lacrosse^ | 4-year | $20.92 | $10.51 | -$6.94 | -$3.37 | | | | $5.28 |
| | 3-year | $23.77 | $35.00 | $6.95 | $23.66 | | | | $22.35 |

Φ Yields of same crops in different rotations and plots were averaged at harvest.
Ω In 2003, winter wheat was seeded across all plots, but the plots were harvested separately.
# Economic data not available.
^ Economic data for this site provided by Monsanto's Center for Excellence project.

*Statistical analysis*

For this project, the purpose of statistical analysis was to provide an estimate of how reliably one factor (in this case usually a crop rotation) would perform better than another factor/rotation in any crop season, so that farmers could decide which was more beneficial for their operation. In order to demonstrate what we call "statistical significance," 1 rotation must perform better than another pretty consistently across the locations and seasons tested. The more replications (locations and years) included in the test, the more reliably the data will indicate relative performance. Although we started out with 8 site replications, for various reasons we ended up with 4 that went through the whole 6 seasons. Within these replications, further data was lost due to planting or harvesting errors. Trying to meld practical farming decisions, i.e., varying crop choices with the seasonal conditions and price also complicated the analysis. Using a very rigid design, however, may provide a more definitive, but limited result that has less practical applicability for the farmer. Ultimately, the final dataset was considerably smaller than planned, which reduced the power of the statistical analysis.

A summary of the statistical comparisons made is in Table 3. For each comparison we compared the overall 4-year rotation with the overall 3-year yields (lb/A) and net return ($/A) across all sites and at individual sites. We also included variations of these rotations: the reverse 4-year (spring wheat followed winter wheat), the alternate 3-year (a broadleaf crop substituted for chemical fallow), a mixed 3-year (chemical fallow or broadleaf used as appropriate for the season).

Table 3. Summary of statistical comparisons between crop rotations made on the Northwest Crops Project data.

| Sites included | Comparisons made; 4-yr rotation vs. 3-yr rotation | Variables analyzed | Statistical significance |
|---|---|---|---|
| Colfax, Dusty, Lamont | 4-yr 1998-2001 vs.<br>3-yr 1998-2000 & 1999-2001 | Yield (lb/A),<br>Net return ($/A) | All NS (not significant) |
| Colfax, Dusty, Lamont | 4-yr 1999-2002 vs.<br>3-yr 1999-2001& 2000-2002 | Yield (lb/A),<br>Net return ($/A) | All NS |
| Colfax, Dusty, Lamont | 4-yr 2000-2003 vs.<br>3-yr 2000-2002 & 2001-2003 | Yield (lb/A),<br>Net return ($/A) | All NS |
| St. John | 4-yr vs. 3-yr, 2001-2003 | Net return ($/A) | NS |
| Lacrosse | 4-yr 1997-2000 vs.<br>3-yr 1997-1999 & 1998-2000 | Net return ($/A) | First comparison,** second comparison NS |
| Pomeroy | 4-yr 1998-2001 vs.<br>3-yr 1998-2000 & 1999-2001 | Net return ($/A) | Both NS |
| Pomeroy | 4-yr 1999-2002 vs.<br>3-yr 1999-2001 & 2000-2002 | Net return ($/A) | Both NS |

** = Net returns of rotations compared were significantly different at the 5% probability level.
NS = Not a significant difference statistically.

The analyses also accounted for missing plots and planting and harvesting errors, though this effectively reduced the size of the dataset and the power of the analysis. The economic analysis included both the custom harvest rate for corn used at the Colfax, Dusty, and Lamont sites as well as an estimation of the growers' cost had they harvested the corn themselves.

Although in many of the comparisons we made, we could not detect consistent/statistical differences between rotations, it does not mean that those differences do not exist and that the 3-year and 4-year rotations will perform identically on any particular farm. Although the sites chosen had similar soil types and broad precipitation amounts, there were actually considerable differences among these locations, which also masked differences between the rotations. Having more replications of the rotations at each site would have overcome this problem, but would have been unwieldy for the farmers to manage. Although we cannot make recommendations from many of these comparisons, by looking at the average yields for a nearby site, a farmer can get a sense of which rotation tended to be more risky or beneficial. Also, although a small yield difference may not earn statistical merit, when multiplied across several hundred acres it may make a big economic difference to the farmer. The farmer has to make a management decision, so it is preferable to go with the option that looks best (or least risky) even if it is not statistically better.

Of the combined and individual site comparisons between the 4-year and 3-year rotations at Colfax, Dusty, and Lamont, the only statistical difference revealed that, in some comparisons, the 3-year rotation over the years 2000 to 2002 had a higher net return than the 4-year rotation over 2000 to 2003. This was not consistent and was probably largely attributable to the very low returns obtained in 2003 due to dry conditions. We did not have data for all 6 years from St John, Lacrosse, and Pomeroy. Individual analyses at these sites generally showed no statistical differences between the 3-year and 4-year rotations. However, at Lacrosse, the 3-year rotation over 1997-1999 did have a higher net return than the 4-year rotation, 1997-2000.

Overall, we did not see consistently better performance by either rotation. This has some positive connotations, i.e., choosing a rotation due to current commodity price, climatic conditions, and situations on one's own farm is probably adequate.

In order to determine the specific benefits of individual crops in rotation, we also compared yield and net return of winter and spring wheat following different crops (Table 4). Although our primary intent was to evaluate whole crop rotations, we also compared the yield and net return of corn and barley (Table 4) as the cooperators hoped that corn would occupy a similar rotational slot as barley and possibly confer some agronomic benefits.

Table 4. Yield (lb/A) and net return ($/A) of crop sequences and crop comparisons made independent of the crop rotation within the Northwest Crops Project.

| Sites included in the analysis | Comparisons made | Average yield (lb/A) | Net return ($/A) |
|---|---|---|---|
| Colfax, Dusty, Lamont<br>St John, Pomeroy, Colton | WW Φ after SP versus<br>WW after SW | 3794**<br>2785 | 65.48 **<br>11.75 |
| Dusty, Lamont | WW after SM or SCN vs.<br>WW after SW | 3088 NS<br>2906 | 25.05 NS<br>17.55 |
| Colfax, Dusty, Lamont<br>St John, Pomeroy, Colton | WW after SBL vs.<br>WW after SW | 3757 **<br>2785 | 63.71 **<br>11.75 |
| Dusty, Lamont | WW after SP vs.<br>WW after SM or SCN | 3520 NS<br>3088 | 42.92 NS<br>25.05 |
| Colfax, Dusty, Lamont<br>St John, Pomeroy, Lacrosse | WW after CF vs.<br>WW after SW | 3750**<br>2882 | 53.33 **<br>17.11 |
| Colfax, Dusty, Lamont<br>St John, Pomeroy | WW after CF vs.<br>WW after SP | 3436 NS<br>3879 | 48.90 NS<br>65.48 |
| Dusty, Lamont | WW after CF vs.<br>WW after SM or SCN | 2961 NS<br>3088 | 24.96 NS<br>25.05 |
| Colfax, Dusty, Lamont<br>St John, Pomeroy | WW after CF vs.<br>WW after SBL | 3436 NS<br>3836 | 48.90 NS<br>63.71 |
| Dusty, Lamont | SW after WW vs.<br>SW after SP | 2534 NS<br>2862 | -1.79 NS<br>9.55 |
| Colfax, St John, Colton,<br>Lacrosse | SW after SW vs.<br>SW after SP | 3015 NS<br>2539 | -15.28 NS<br>-12.52 |
| Dusty, Lamont | SW after WW vs.<br>SW after SBL | 2534 NS<br>2682 | -2.95 NS<br>4.18 |
| Colfax, Dusty, Lamont | Corn vs.<br>Barley | 2150 NS<br>2346 | -46.72 NS<br>-35.75 |

Φ WW = winter wheat, SP = spring peas, SW = spring wheat, CF = chemical fallow, SBL = spring broadleaf (including peas, canola, mustard), SM = spring mustard, SCN = spring canola.
** Indicates means different at 5% level of probability.
NS = not a significant difference statistically.

In Table 4, the analyses that included the greatest number of experimental sites had the greatest number of data points. In these situations, differences in yield or net return are more likely to be statistically different. Where the data was collected from only 2 sites, there were usually very few data points and what appeared to be large differences in yield or net return did not analyze as significant.

Planting winter wheat following spring peas or following any broadleaf (peas, mustard, or canola) provided yield and economic advantages over seeding it following spring wheat. It would appear that spring peas conferred most of the benefit (*Note*: peas use 1 to 3 inches less moisture than spring wheat), as there was no significant advantage to planting winter wheat following spring canola or mustard alone. However, having small data sets and including 1 site that experienced very dry seasons probably compromised the analyses involving spring canola or mustard alone.

Winter wheat yields and net return following chemical fallow were significantly better than following spring wheat. However, the broadleaves, peas, canola, and mustard, tended to improve (but not significantly) the yield and net return of subsequent winter wheat crops more than chemical fallow. So, in years with adequate moisture it would be better to grow a broadleaf crop rather than spring wheat, instead of having chemical fallow. In this project we did not have a rotation with winter wheat following spring barley.

Although not significant, the trends showed it was preferable to plant spring wheat after a spring broadleaf than after winter or spring wheat. An important aspect of all these analyses was that the sequences occurred in several crop years and on different farms, so the differences in yield and net return might well be due to variations in location and season rather than a rotation effect.

When comparing corn from the 4-year rotation with barley from the 3-year rotation, the yields and net returns were not significantly different though corn tended to yield less and cost more to produce than did barley.

*Experiential observations*

Much of the value of the project was in learning together as a group, and being able to discuss challenges with other farmers having similar experiences. Following are some of the things we learned and observed in the course of the project.

- The region is capable of growing many diverse crops, besides wheat and barley or peas and lentils. We experimented with garbanzos (chickpeas), mustard, canola, and corn.
- Our experience with corn (a warm season crop) was variable. Despite the agronomic difficulties, some farmer cooperators were successful and along with their friends, families, and neighbors, they saw that with proper management we can grow corn in this region. Other growers had too many problems and decided that growing corn did not provide any economic gain for their operation even though it did show some signs of rotational benefits. However, corn is not likely to succeed every year as temperature (growing degree days) and summer moisture tend to be limited.
- We learned about corn planters and harvest headers, timing of seeding, seeding rates and depths, plus the importance that each plays in raising a corn crop. We learned about corn markets, local demand or lack thereof, and where to ship corn that was too high in moisture content for local storage. We also learned about problems with small corn acreage from deer, elk, and birds feeding on the crop, and that late spring frost and early fall frosts that can really affect the final crop yield.
- By using a small seed corn, growers were able to use their own drills for seeding, and they could harvest the corn with their grain header, thus eliminating the extra costs of renting a corn planter and harvest equipment. The limiting factor to harvesting corn with a grain header was crop yield; up to 75 bu/A (2 tons/A) it was feasible, but above that the grain header was not able to process the biomass and many corn cobs were lost.
- However, at the end of the project, 3 of the growers were sufficiently optimistic to purchase the corn planter and they seeded corn in the spring of 2004. At least 2 other growers intend to use the small

seeded varieties and their own equipment to raise feed corn for livestock on their own and neighboring farms.

- Other crops tried during this project included chickpeas, mustard, and canola, with the same outcome as the corn; they worked for some farmers and not others. Factors included environmental conditions, especially too much or too little rainfall; wildlife damage; and lack of knowledge in growing new crops. However, these crops have potential in rotation, but marketing and processing them remain a major bottleneck in their economic viability.
- The project cooperators used many different drill types, and all worked well in most situations. The disk opener drills handled heavier residue better than did hoe type drills simply because of less disturbance to the soil, but we saw some problems with all types when the residue or stubble was over 85 bu/A. We did see hairpinning of residue with disk openers in heavy residue, which reduced plant stands in those areas.
- An air seeder will seed corn if adjusted properly. A slow-speed drive was necessary on a JD 752 box drill for seeding corn. However in a comparison at the Pomeroy location, corn planted in 15-inch rows with a JD 752 drill yielded 86 bu/A compared with a 106-bushel per acre yield obtained with a JD corn planter and 30-inch spacing. Research in the Midwest shows that corn seeds emerging side-by-side within 3 to 4 inches of each other compete, and actually inhibit each other (*Pioneer Hybrid Production Manual*).
- The drills seemed able to handle the different-size seed for the different crops, but we had to tape small holes in drill boxes and tubes to prevent mustard or canola seed from leaking out.
- Direct seeded corn usually had sufficient moisture during tasseling in July to set ears. In 2 trials at Uniontown, corn planted in a cultivated field never set ears due to lack of moisture at tasseling. Direct seeding affords the farmer more cropping options, such as a C-4 (warm season) crop in rotation.
- Growers at Dusty, Colfax, and Pine City achieved an unusually high winter wheat yield in 1 or more years when they had corn in the rotation. This was due possibly to less disease pressure from soilborne pathogens (personal communication from Dr. R. James Cook). However, a supplemental study of soilborne pathogens at these sites has not shown a huge sanitation effect from growing corn (see Appendix A).
- The cooperator at Dusty noted from his plots that if the corn and peas at least broke even financially, the 4-year rotation would be more profitable than the 3-year rotation.

**References**

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## Appendix A. Soilborne Pathogens and Root Diseases

No disease or pathogen measurements were made over the course of these rotation studies at the farmer sites. However, in Fall 2003, soil samples were taken from the rotations at the end of the experiment at the farms near Colfax, Dusty, and Lamont. These samples were sent to Australia for DNA analysis by SARDI (South Australian Research and Development Institute) (Ophel-Keller 2003). This test provides a quantitative analysis of the pathogen populations in the soil, based on picograms DNA/g of soil. With this method, DNA is extracted from soil, and PCR primers specific to each pathogen are used to amplify the DNA. The following pathogens are detected by this test: *Gaeumannomyces graminis* var. *tritici* (take-all), *Rhizoctonia solani* AG8, (*Rhizoctonia* root rot), *Heterodera avenae* (cereal cyst nematode), *Pratylenchus neglectus*, and *P. thornei* (lesion nematode); *Fusarium pseudograminearum* and *F. culmorum* (Fusarium crown rot) and *Bipolaris sorokiniana* (common root rot).

We hypothesized that root diseases result from inoculum in the soil and residue, which are produced during the previous year(s) of cropping. These pathogens produce resistant spores (*Fusarium, Bipolaris*) or survive as mycelium in decaying roots (*Rhizoctonia, Gaeumannomyces*). This test also detects 3 important nematodes: cereal cyst nematode (*Heterodera*) and 2 species of lesion nematode (*Pratylenchus*).

It is well known that crop rotation will influence certain root pathogens, if one of the crops is a non-host or if there is no crop (fallow). During this unfavorable period for the pathogen, inoculum in the soil will decline over time, due to microbial attack, feeding by soil invertebrates, or loss of energy through respiration. In any case, the inoculum level of certain pathogens will be reduced following crop rotation and fallow, and we hypothesized this test would detect these differences.

### Materials and Methods

Soil samples were taken in Fall 2003 from fields that had been in various rotations since 1997. There were a number of different rotations:

4-year - the standard Beck rotation - SW-WW-corn-spring broadleaf

4-year - reverse - WW-SW-corn-spring broadleaf

3-year standard - WW-SB-chemical fallow

3-year alternate - WW-SB-spring broadleaf

3-year mixed - WW-SB-chemical fallow or spring broadleaf

Because of the unbalanced design, not every rotation was sampled equally. Table 1 shows the number of samples from each rotation at each location.

Table A1. Number of samples from each rotation.

| Site | 4-yr | 4-yr reverse | 3-yr standard | 3-yr alternate | 3-yr mixed |
|---|---|---|---|---|---|
| Colfax | 4 | 0 | 1 | 0 | 2 |
| Dusty | 4 | 4 | 3 | 0 | 0 |
| Lamont | 3 | 3 | 2 | 2 | 2 |

For each sample, approximately 1 kg of soil was dug from the upper 6 inches. Soil was air-dried and frozen at -20°C for 2 weeks before being sent to Australia. The freezing was a quarantine requirement to kill any insects in the soil. Results were received in a spreadsheet as picograms DNA/g soil. DNA levels were log transformed after adding 1 to each of the values, in order to make the data normally distributed. ANOVA was performed using rotation and strips as main factors. Means were separated with LSD at $P$=0.05. If data was not normally distributed after transformation, means were separated with Kruskal-Wallis One-Way non-parametric ANOVA. Risk levels were also assigned to the values, based on Australian conditions, but may not be applicable to our conditions.

Because of the unbalanced designs and the lack of replicates of some rotations, the following comparisons were made:

1. At the Colfax and Lamont sites, the standard 3-year rotation was compared with the mixed and alternate 3-year rotations.

2. At the Dusty and Lamont sites, the standard 4-year rotation was compared with the reverse 4-year rotation.

3. All 4-year rotations were compared with all 3-yr rotations, using data from all 3 sites.

Only *Rhizoctonia solani, Fusarium culmorum,* and *Fusarium pseudograminearum* were analyzed statistically, since the level of the other pathogens were low or below the detection limit.

**Results and Discussion**

The take-all pathogen, *Gaumannomyces graminis* var *tritici*, was below detectable levels in all samples taken. This pathogen is normally not a problem in the normal 3-year or 4-year rotations in eastern Washington that contain a non-host broadleaf crop (peas, chickpeas, lentils, canola, sunflower, safflower, buckwheat, flax), a fallow, or a non-host monocot (corn, oats, millet). This data fits the observations of numerous studies on this disease over the past 50 years.

The cereal cyst nematode was not detected in any samples. This nematode is a problem in northeast Oregon and the Willamette Valley, but has not been detected in the dryland areas of Washington. *Pratylenchus neglectus*, the root lesion nematode, was only detected in 5 out of 7 samples in Colfax, but in 10 out of 11 samples from Dusty. In Lamont, only 1 out of 14 samples contained *P. neglectus*. *P. thornei*, the more virulent of the 2 species, was found in only 1 sample.

These nematodes have been implicated in yield losses on cereals in Oregon (Smiley, personal communication and submitted manuscripts). They have a wide host range, with wheat being the most preferred host, followed by barley. They can also reproduce on broadleaf crops, but there is variability among species and cultivars in terms of reproductive success.

*Rhizoctonia solani* was detected at all 3 sites. In Colfax, it was detected in 3 out of 7 samples, at a high level in 1 and a medium level in 1. In Dusty, *Rhizoctonia* was detected in 4 out of 11 samples, and in 10 out of 14 samples in Lamont. At Lamont, 4 of the positive samples had a medium level and 1 had a high level of DNA.

*Fusarium pseudograminearum* was predominant over *F. culmorum* in all sites, similar to other data from low and intermediate rainfall areas. In Colfax, 5 out of 7 samples contained *F. pseudograminearum,* with levels ranging from low to high. In Dusty, 6 out of 11 samples contained *F. pseudograminearum,* but only 3 out of 14 samples were positive at Lamont.

*Bipolaris sorokiniana* was below the detection limit in all samples, except for 1 in Colfax.

**Comparison of 3-year rotations**

There were no significant differences between the Colfax and Lamont sites, and no interactions between site and rotation, so the results were pooled among the 2 sites (Table 2). There was no significant effect of the type of 3-year rotations on the DNA levels of *Rhizoctonia* or *Fusarium.* This suggests there is no difference between chemical fallow and a spring broadleaf rotation crop. This makes sense for *Fusarium*, since the spring broadleaf crop should not be host for these pathogens. However, *R. solani* can also infect broadleaf rotation crops, so these results do not fit our theory.

Table A2. Comparison of 3-year rotations.

| Rotation | *Rhizoctonia solani* [log (pg DNA/g soil +1)] | *Fusarium culmorum* [log (pg DNA/g soil +1)] | *Fusarium pseudograminearum* [log (pg DNA/g soil +1)] |
|---|---|---|---|
| 3-yr standard | 0.58 | 0.07 | 0.07 |
| 3-yr mixed | 0.89 | 0.47 | 1.42 |
| 3-yr alternate | ND | ND | ND |
| P | NS (0.31) | NS (0.59) | NS (0.13) |

ND = not determined, not enough degrees of freedom.

**Comparison of 4-year rotations**

There were no significant differences between the Dusty and Lamont sites, and no interactions between site and rotation, so the results were pooled among the 2 sites (Table 3). There was no significant effect of the type of 4-year rotations on the DNA levels of *Rhizoctonia* or *Fusarium.* This would be expected, since spring and winter wheat are both susceptible to these pathogens, and reversing the order of the cereals should not create a difference.

Table A3. Comparison of 4-year rotations.

| Rotation | *Rhizoctonia solani* [log (pg DNA/g soil +1)] | *Fusarium culmorum* [log (pg DNA/g soil +1)] | *Fusarium pseudograminearum* [log (pg DNA/g soil +1)] |
|---|---|---|---|
| 4-yr standard | 0.80 | 0.27 | 0.63 |
| 4-yr reverse | 1.01 | 0.34 | 0.41 |
| P | NS (0.56) | NS (0.74) | NS (0.38) |

**Comparison of 3-year with 4-year rotations**

There were no significant interactions between site and rotation, so the results were pooled among the 3 sites (Table 4). There were no significant differences among sites, except for higher levels of *F. pseudograminearum* at the Colfax, compared with the other sites. *Rhizoctonia solani* and *F. pseudograminearum* did not show any rotation effect. However, there were higher levels of *F. culmorum* in the 4-year rotation, compared with the 3-year rotation. But, for *F. culmorum,* the interaction between site and rotation was close to significant (0.06), and a closer examination of the data showed this rotation effect was most pronounced at the Colfax site, but was not very pronounced at the Dusty site, while the trend was reversed at the Lamont site.

A general conclusion is that including a warm-season grass in the rotation does not affect the level of these 3 pathogens. *Rhizoctonia solani* can also infect corn and millet, although it may be a different AG type than the AG-8 detected here. *F. culmorum* also infects both corn and millet. The host range of *F. pseudograminearum* on these warm-season grasses is not really known. This species was previously grouped with *F. graminearum*, which is a well-known pathogen on corn and millet. But, given the ability of these 3 pathogens to also infect the warm-season grass, a 4-year rotation would not give any additional rotation benefit.

Table A4. Comparison of 3-year with 4-year rotations.

| Rotation | *Rhizoctonia solani* [log (pg DNA/g soil +1)] | *Fusarium culmorum* [log (pg DNA/g soil +1)] | *Fusarium pseudograminearum* [log (pg DNA/g soil +1)] |
|---|---|---|---|
| 3-yr | 0.80 | 0.21 | 0.77 |
| 4-yr | 0.83 | 0.58 | 0.83 |
| P | NS (0.92) | 0.05 | NS (0.84) |

**General Conclusions**

Based on the DNA results, the risk of most soilborne pathogens at these sites was rather low. The only exception was the level of *Rhizoctonia* at the Lamont site, which was higher than the other sites. This agrees with my sampling and previous observations at these farms, as part of other research projects. We have often seen patching and uneven stands in the Lamont area, indicative of *Rhizoctonia,* but we have not seen these symptoms at the Colfax site. At the Colfax site, the major pathogen was *F. pseudograminearum* and was in high enough levels to probably cause yield losses in low-rainfall years. In general, however, including a warm-season grass in the rotation does not affect the level of these 3 pathogens, because these crops (corn and millet) also support these pathogens.

## References

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## Appendix B. Soil Quality Analysis

### Materials and Methods

We collected information for soil quality analysis in the spring of 1998 and 2003. The parameters we measured were soil pH, organic matter (OM), and bulk density.

In April 1998, soil samples were collected from each plot at all 7 locations in the study. For soil pH and organic matter analysis, 6 soil cores were taken from a transect running in the center of the plots along the length of the plot at 3 depths (0 to 2, 2 to 4, and 4 to 12 inches). After mixing, a small composite sample was taken from the field, air-dried, crushed, passed through a 2-mm screen, and stored until analysis.

Soil organic matter and pH were measured at the Rock Creek Conservation Office. Soil pH was measured on a saturated paste; soil organic matter was by a colorimetric method.

Four soil bulk density samples were collected from a 4-6" depth with a hammer-driven soil core device from each plot. A small hole (10" x 10" x 6" deep) was excavated in each plot so we could count earthworms. Only 1 site, (Pomeroy) had earthworms distributed throughout the plots.

In May and April 2003, 4 of the 7 growers remained in the study. We repeated the sampling and analysis conducted in 1998 on those sites, with the exception of earthworm counts.

### Results and Discussion

We did not conduct statistical analyses on these data. However, there appeared to be an increase in bulk density at the sites shown (Table B1). This might indicate the development of compaction layers that have been shown to develop after several years of direct seeding.

Table B1. Bulk density (lb/cubic foot) of soil samples from Northwest Crops Project sites in 1998 and 2003.

| | 1998 Sampling (lb/cubic foot) | | | | 2003 Sampling (lb/cubic foot) | | |
|---|---|---|---|---|---|---|---|
| | **Mean** | **Low value** | **High value** | | **Mean** | **Low value** | **High value** |
| Colfax | 72.6 | 64.6 | 82.2 | | 76.2 | 74.3 | 79.9 |
| Dusty | 71.4 | 61.8 | 79.3 | | 76.2 | 71.8 | 84.9 |
| Pomeroy | 73.9 | 66.8 | 79.9 | | 71.2 | 69.3 | 73.0 |
| Lamont | 74.6 | 58.7 | 86.8 | | 76.2 | 73.0 | 78.7 |
| | | | | | | | |
| Colton | 72.2 | 61.7 | 81.6 | | | | |
| St. John | 63.2 | 51.2 | 77.4 | | | | |
| Lacrosse | 70.5 | 60.6 | 76.2 | | | | |

We did not see any consistent changes in soil organic matter (Figure B1) or soil pH (Figure B2) between 1998 and 2003.

Figure B1. Soil organic matter at 3 Northwest Crops Project locations in 1998 and 2003.

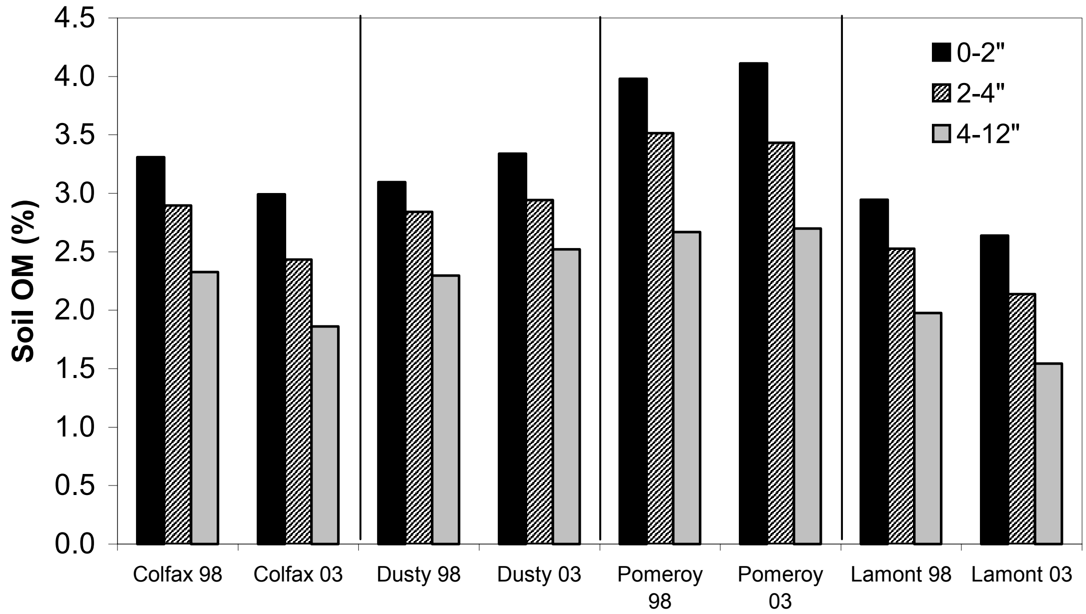
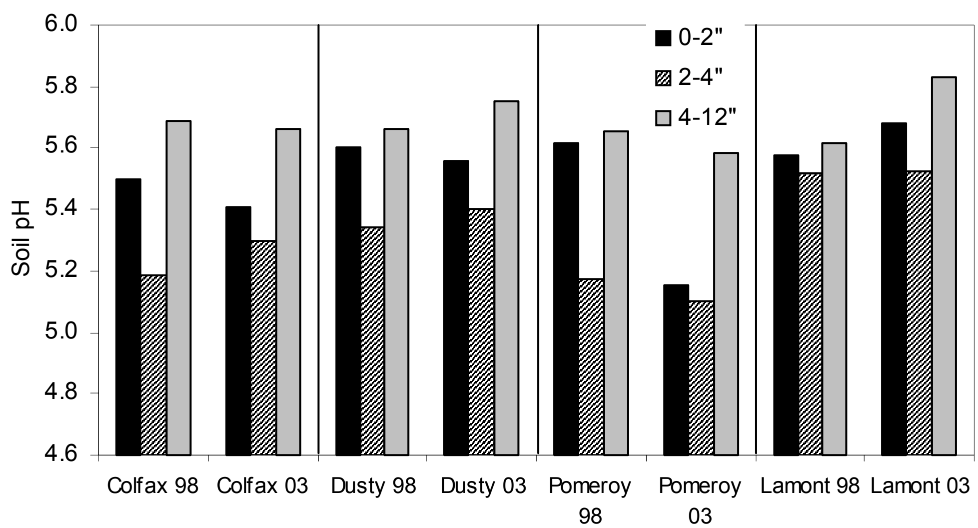



Figure B2. Soil pH at 3 Northwest Crops Project locations in 1998 and 2003.



## Appendix C. Corn Harvest Method Comparisons

Table C1. Comparison of corn yields obtained by hand harvest and combine harvest conducted at Pine City, Fall 2003.

| | Yield estimate from hand harvest (bu/A) corrected to 15% moisture | Yield from field harvest with combine (bu/A) Φ corrected to 15% moisture | Difference (%) between hand harvest estimate and combine harvest |
|---|---|---|---|
| Plot 1 (Integra 7175) | 56.1 | 63.0 | -11.0 |
| Plot 2 (Canamaize) | 37.7 | 38.6 | -2.3 |
| Plot 3 (Integra 7175) | 40.5 | 39.5 | +2.5 |
| Φ The wheat combine header lost about 25% of corn cobs during harvesting, so the yield was adjusted to account for this. | | | |